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Modeling Surface Mass Load Displacements Along The Cascadia Subduction Zone

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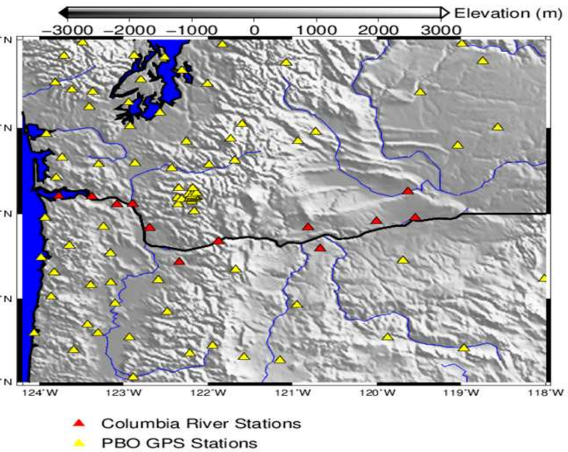
Introduction

Columbia River along the Washington-Oregon border. Mass loading from the water exerts force on Earth's surface, deforming its shape.

- **What is Earth's response to hydrologic loading, such as changes in river discharge and seasonal snowpack?**
- Earth's surface is under constant strain from different **mass loads**, such as the oceans, atmosphere, and continental water reservoirs.
- **Surface Mass Loads** exert forces on the Earth, changing the shape of Earth's surface.
- Horizontal and vertical displacement responses caused by mass loads are recorded using **Global Positioning System** (GPS) receivers.
- Modeling and removing mass load signals in the GPS time series can reduce variance and improve accuracy of the time series.
- Important to remove mass load signals because small plate motions may be hidden inside the data.
- My project focuses on using Python-based software program **LOADDEF** to model contributions of mass loads to GPS time series in Cascadia.
- Currently modeling Hydrologic (HYDL) and Atmospheric (ATML) Loading along the Columbia River.
- Want to compare precipitation with surface displacement.

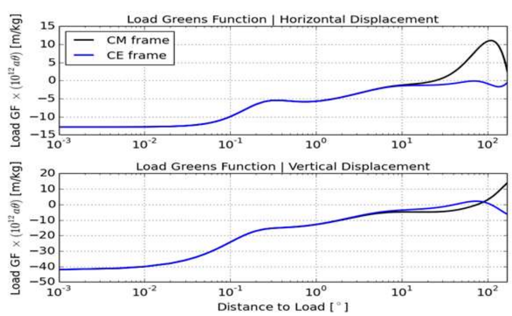
PBO Station P449 (LEFT) located near the Columbia River. PBO Station P144 located in Sierra Nevada Mountains, Northern California. GPS receivers powered by solar panels.

Methods



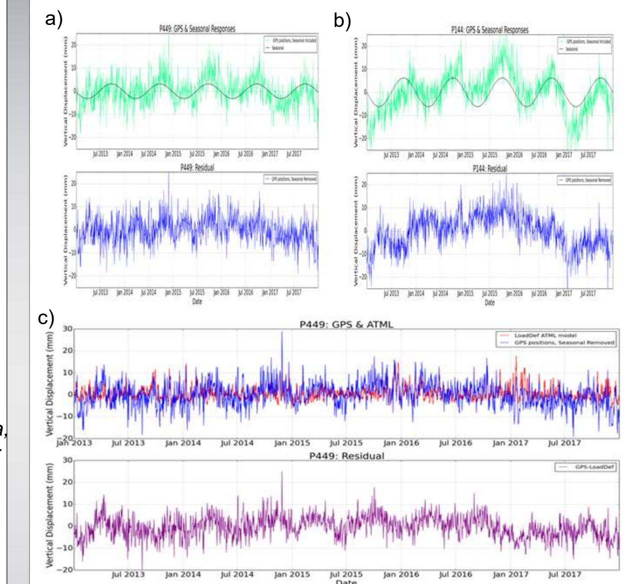
Station Locations: PBO GPS stations are distributed through Cascadia, monitoring surface displacements. Stations along the Columbia River (RED) used to compare vertical displacement with river outflow.

- ECCO, ECMWF, GRACE datasets downloaded for non-tidal oceanic, atmospheric, water loading.
- GPS data downloaded from UNAVCO website.
- Scripts written to process and plot GPS data.
- Use load Green's Functions to model displacement caused by atmospheric and hydrologic mass loads.
- Compare results to observed displacement measured by the Plate Boundary Observatory (PBO).
- Subtract modeled mass load from GPS time-series
- Compute variance for residual time series.



Plot of load Green's Functions. Green's Functions describe the response of the elastic earth to various surface stresses.

Early Results

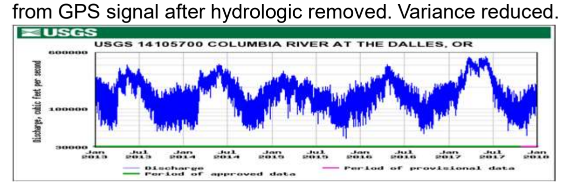


GPS data process: 2013-2017 from P449 and P144.

a) Columbia River Station P449: Original GPS signal (green) and hydrologic signal (black). Subtracting hydrologic signal from GPS signal results in more accurate residual (blue).

b) Sierra Nevada Mountain Station P144: same as (1). Note the larger hydrologic signal. This is caused by snowpack.

c) Columbia River Station P449: Removal of atmospheric signal from GPS signal after hydrologic removed. Variance reduced.



USGS Columbia River Station records river discharge. Will use peak river discharge to determine correlation with GPS displacement, as well as annual precipitation for Cascadia.

Future Work

- Expand methods to all stations in Western US
- Find how much of GPS signal caused by mass loads
- Map contributions of each mass load along Cascadia

1. Martens, H.R., L. Rivera, and M. Simons, 2016. *LoadDef User Manual*, *version 1.1.0*, California Institute of Technology. earthdef.caltech.edu
2. Argus, D. F., Landerer, F. W., Wiese, D. N., Martens, H. R., Fu, Y., Famiglietti, J. S., … Watkins, M. M. (2017). Sustained water loss in California's mountain ranges during severe drought from 2012 to 2015 inferred from GPS. *Journal of Geophysical Research: Solid Earth*